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ABSTRACT

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STUDENTS' RESPONSES DURING DISCREPANT EVENT SCIENCE LESSONS

ED 393 696

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Abstract

This study explored the cognitive responses of students to science lessons incorporating discrepant events. Three pedagogically different teaching strategies using the same discrepant event were taught to six upper elementary classes, and case studies describing eighteen students' cognitive responses during the lessons were constructed from video tapes of the lessons, stimulated recall interviews with the students, and field notes. A common set of cognitive responses were identified for most students for all three teaching strategies. A small number of responses seemed to depend on the student. However, the teaching strategy also seemed to influence the responses used by students, in that some types of responses were encouraged by a particular teaching strategy, and the use of other responses was inhibited by a particular teaching strategy. The significance of the social context in influencing the students' access to information and their progress toward the scientific explanation was highlighted. The results provide some indications as to how a more effective teaching strategy might be developed which increases the number and range of cognitive responses used by students.

Students' Responses during Discrepant Event Science Lessons

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The use of discrepant events to introduce science lessons has been advocated for many years (e.g. Friedl, 1986; Liem, 1987; Thompson, 1989; Suchman, 1966; Wilson & Armstrong, 1973). Discrepant events, sometimes called counter-intuitive events, are science activities which have some unexpected or unanticipated outcome, where the student would "see something happen that contradicts his [sic] expectations about the way it should happen" (Suchman, 1966, p. 7). Their purpose was seen to be a stimulus and focus for subsequent inquiry. They are believed to motivate students (Suchman, 1966; Thompson, 1989) and have been shown to be effective in facilitating cognitive gains in students (e.g. Johns, 1971; Liem, 1980; Marlins, 1973).

In recent moves toward basing science instruction on constructivist principles of learning (e.g. Appleton, 1993; Gallagher, 1992; Roth, 1994; Wheatley, 1991), there have been suggestions that cognitive conflict should be generated in students as an early teaching step in order to achieve cognitive change (Posner, Strike, Hewson, & Gertzog, 1982). That is, students should be made aware of the inadequacies of their own explanations of phenomena by contrasting them with the scientific explanation. Rowell and Dawson (1983) investigated the role of "empirical counter-examples" in cognitive change, based on cognitive conflict strategies emerging from Piagetian theory (Piaget, 1964). The counter-example they used could therefore be viewed as a type of discrepant event, though they did not apply that term to their study. They contrived a situation where students would be confronted with a cognitive discrepancy, and looked at how students reacted when confronted with an event contrary to a theory they had just (implicitly) outlined. Nussbaum and Novick (1982) also used discrepant events to generate cognitive conflict as part of a teaching strategy that would encourage accommodation (Piaget, 1964). They used a discrepant event as the second step in their suggested teaching strategy, after the students' preconceptions had been exposed, compared and discussed. The discrepant event used by Nussbaum and Novick was not designed to be attention-getting or used as a motivating experience as such. It was designed to be an empirical challenge to a known misconception held by the students, so that the misconception would be reexamined and possibly replaced by the accepted scientific idea. It seems that the purpose and nature of such discrepant events make them different from those used as motivators to introduce lessons and units of work.

Further, while theories of cognitive change based on the generation of cognitive conflict focus on changes within the learner and his/her personal constructs, the social context is also seen to play an important part in facilitating cognitive change (e.g. Driver, Asoko, Mortimer, Leach, & Scott, 1994; Tobin, 1990). A key aspect of the social context is the teaching strategy in which the discrepant event is embedded. The teaching strategy could well be expected, then, to influence the cognitive responses of students.

In the discrepant event literature, three prominent authors seem to have used them as a basis for curriculum, and have included a proposed pedagogy for their use (Friedl, 1986; Liem, 1987; Suchman, 1966). All three justified using discrepant events as the basis for curriculum in terms of their being a basis for further inquiry. They drew on the Piagetian idea of *disequilibrium*, though Liem also showed how Festinger's (1957) theory of cognitive dissonance can be related to discrepant events. The cognitive conflict generated by a discrepant event was seen by all as a key element of its success. Since the use of discrepant events was justified in terms of Piagetian theory, namely cognitive conflict, they could be considered as being based on constructivist principles of learning. However, each author differed in the suggested means of helping students resolve the cognitive conflict. The different teaching strategies outlined therefore varied in the degree to which they might relate to other constructivist views of facilitating cognitive change.

The Focus of the Study

This study reexamined how discrepant events might fit within constructivist-based pedagogies. In these, there is a focus on the students and their learning (Osborne & Freyberg, 1985), and the social context (Driver, Asoko, Mortimer, Leach, & Scott, 1994). There is an expectation that, as a result of such pedagogies, students will experience cognitive change using thinking processes (Lawson, 1994). However, little is known about the cognitive responses (processes) of students to many such pedagogies, including those using discrepant events. This study was therefore designed to explore this aspect, and add to the knowledge about students' learning during a number of discrepant event pedagogies which differed in their alignment with constructivist principles. Such knowledge would provide useful feedback about the effectiveness of the selected pedagogies in constructivist terms, and point to ways of making improvements in their effectiveness.

Specifically, this study explored the cognitive responses of students to science lessons incorporating discrepant events. Three pedagogically different teaching strategies using discrepant events were selected to include the range of strategies which might be used in schools. However, since the strategies were obtained from the discrepant event literature, they differed in their degree of alignment with constructivist principles, and could therefore be expected to influence the cognitive responses of the students in different ways. The research questions were:

(1) What cognitive responses are evident in students during discrepant event lessons?
(2) Do students respond differently to different discrepant event teaching strategies?

Likely Cognitive Responses to Discrepant Events Derived from the Related Literature

Discrepant events have been linked to Piagetian theory (Liem, 1987; Suchman, 1966; Thompson, 1989), cognitive dissonance theory (Liem, 1987), and problem solving (Stonewater & Stonewater,

1984; Thompson, 1989), so the literature in these three areas provides some indications of likely student responses.

From Piagetian thought, possible responses would include wanting to know a solution to explain the discrepant event, ignoring or discounting the discrepant event in some way, and adjusting mental schema to accommodate the event (Piaget, 1978). According to dissonance theory, students' responses might be information-seeking behaviour to either resolve the dissonance or to support a possible explanation, avoidance or withdrawal from participation for fear of failure or as a means of obtaining information with a minimum of effort, or being non-committal about possible answers (Festinger, 1957; Festinger & Aronson, 1989). The problem solving literature suggests that, in line with the constructivist view of schema activation (Claxton, 1990; Piaget, 1964), students experiencing a discrepant event would construct from existing schema a mental representation of the problem they perceive (Marshall, 1995; Newell & Simon, 1972), called the problem space (Green, 1988). Different forms of imagery might be used to represent the problem (Hayes, 1981), and analogies may be used to simplify its representation (Claxton, 1990; Gick & Holyoak, 1983). If no schema were found to adequately explain the problem a search strategy would be initiated (Gick, 1986; Marshall, 1995), usually in the form of information seeking (Dunbar & Klahr, 1989).

In summary, students experiencing a discrepant event could be expected to:

- attempt to explain it using existing schema,
- try to understand the problem more clearly using different forms of imagery such as sketching or analogies,
- search for information which may provide a solution, or which might support a proposed solution,
- avoid making a response, or
- withdraw from participation.

The Study

The methodology employed in this study was consistent with its constructivist theoretical framework. Data were collected in the form of a series of case studies of students who participated in science lessons using discrepant event pedagogies. The case studies were constructed using a combination of data sources: video tapes of the science lessons, interviews with the students using the video tapes to stimulate their recall of the lesson (Edwards & Marland, 1984), and field observations. The interviews were interpreted in terms of Mishler's (1986) notion of interviews as narratives constructed jointly by the interviewer and interviewee.

The students

Three classes of eleven to twelve year-olds, and three classes of twelve to thirteen year-olds (the final two years of elementary school in the state) in urban schools were selected. Four students from each of the first three classes and two from each of the last three were selected for the study. The students, who were nominated by their teachers, were mostly of caucasian extraction.

The discrepant event teaching strategies

The literature was canvassed for teaching strategies using discrepant events. Three pedagogically different strategies which covered the range of strategies which might be used in schools, were selected for the study. The strategy used by Suchman (1966) began with a discrepant event demonstration followed by students asking the teacher questions in a "twenty questions" style to clarify aspects of the event or to test possible explanations using thought experiments, with the possibility of small group student discussions when requested by the students. The teacher neither confirmed nor denied a proposed explanation by a student, and did not provide an explanation. This proved unsatisfactory to both teacher and students, who wanted some closure to the lesson. Liem (1987) also began with a discrepant event demonstration, but followed it with a teacher explanation of the event, using examples and analogies drawn from the students' experiences. Apart from responding to the teacher's questions, the students were passive recipients of the explanation. Friedl (1986) had the students involved in the discrepant event in small groups so, with assistance from the teacher, they could explore the variables which might influence the outcome. Small group and whole class discussions dominated the lesson, with the teacher providing structuring cues about investigating proposed explanatory ideas, and ensuring tests of variables and ideas were valid. Friedl seemed to imply that a solution would be found from the investigation, but in practice, as for the Suchman strategy, a second lesson was found necessary where the teacher summarised findings and explained aspects still unclear. For consistency, the second lessons were not included in the study. Table 1 summarises the main components of each strategy and links to contemporary constructivist thinking.

The discrepant event

The large number of discrepant events described by each author was examined, and one selected which was common to all, and which was considered by a panel of three science educators to present considerable challenge to students. *The Diver* (Suchman, 1966) was selected. In this event, a small bottle was upturned in a tall glass cylinder of water, and adjusted so that it only just floated. A sheet of rubber was fastened over the top of the cylinder and pushed gently. The bottle sank slowly to the bottom of the cylinder and remained there even when the sheet of rubber was removed. When the rubber sheet was pulled upwards gently, the bottle rose to the surface (see figure 1).

Table 1 Components of each strategy and links to constructivist ideas

Strategy	Strategy Steps	Constructivist Links
Suchman	Discrepant event Asking questions about the event or to test an explanation Student discussion in small groups	Cognitive conflict (Piaget, 1964) Students construct their own meaning for the event from existing ideas (Claxton, 1990; Piaget, 1978) Collaborative learning with the group as a community (Driver, Asoko, Leach, Mortimer & Scott, 1994)
Liem	Discrepant event Teacher explanation	Cognitive conflict (Piaget, 1964) Scaffolding by the teacher (Bruner, 1985), with the whole class
Friedl	Discrepant event First hand exploration Student discussion in small groups Teacher structuring cues	Cognitive conflict (Piaget, 1964) Students learn by doing (Piaget, 1964) and making (Papert, 1991) Collaborative learning with the group as a community (Driver, Asoko, Leach, Mortimer & Scott, 1994) Scaffolding by the teacher (Bruner, 1985) with small groups or individuals, and demonstrating how to think in a scientific way (Brown, Collins, & Duguid, 1989)

The lessons

The teachers who would teach the lessons organised among themselves who would use each teaching strategy, and were provided an inservice program highlighting the main characteristics of their selected strategy. The lessons were videotaped, with both the teacher and the selected students on camera. The students were interviewed as soon as possible, the same day of the lesson.

Analysis

The interviews were transcribed, and, using a combination of the data sources, cognitive responses by each student were identified inductively from the data. These were coded using a form of discourse analysis (Cazden, 1988; Edwards & Westgate, 1987), with the system of coding being refined as the definition and meaning of each response was changed to include or exclude particular cognitive behaviours. Interpretation of interview data was based on the idea

that the interview is a narrative constructed jointly by the interviewer and interviewee (Mishler, 1986). Part of the analysis, then, was to identify the narratives being constructed and consequently the real meaning of the discourse. The group of identified and refined responses was then organised under a second hierarchical scheme by grouping them into induced categories with similar foci. A series of case studies for each student for each lesson was then constructed, using the dual system of response categories to identify their cognitive responses and progress through each lesson. The system of emergent cognitive responses was therefore a rationalised and inferred construction of each student's responses through the lesson.

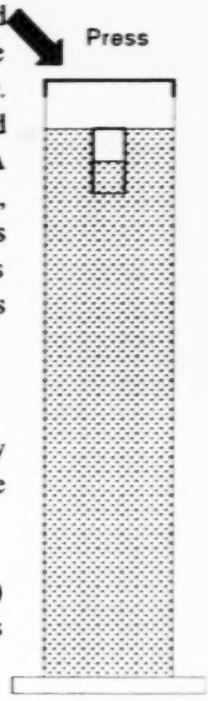

Figure 1
The Diver

Results

The quantity of raw data generated by a study such as this makes it obligatory to present the data in reduced form. However, a few examples from some of the interviews are included so a better feel for the methodology can be obtained.

In each lesson, each student attempted to arrive at a satisfactory (i.e. "correct") solution to the discrepant event. In doing this a variety of cognitive responses was evident. Four categories of cognitive response were induced:

1. Responses in which a remembered idea was used or sought. This was an attempt, successful or otherwise, to relate what was happening to past experiences and/or ideas.

2. Responses in which information was sought from the materials, whether or not direct manipulation was possible.

3. Responses which were made verbally in a social context, to peers in the student's small work group, to the whole class, or to the teacher.

4. Responses which involved receiving information from others in a social context. The others could have been the teacher, or peers either from the student's small work group or from the whole class.

Several types of responses were evident for each of these categories. They are listed, with examples of interview instances, in Tables 2 to 5.

Table 2 Cognitive responses in Category 1: A remembered idea is used or sought

Cognitive Response	Example
Recognising that no explanatory ideas come to mind.	*I was wondering how [the diver] could have gone down. I didn't know how it worked.*
Attempting to think of a reason to account for something.	*I was...trying to figure out how you got [the diver] to go up and down.*
Devising a tentative idea to explain the event.	*I was trying to figure it out if it basically worked on suction an' air pressure.*
Observing a "new" aspect of the event not noted previously.	*So the closer the bottle came to th . . when it hit over that [far] side [of the cylinder] the bottle looked small but when it kept over this side [as it descended] it looked big n seemed to have more water an' air in than when it was over the other side.*
Evaluating an idea in the light of new information.	I: So you were expecting some holes in [the balloon] were you? Peter: *Yeh, just sort of like a pin hole.* I: What made you think there might be a pin hole in there? Peter: *Well just because it looked like air bubbles around it. Around the balloon thing.*
Linking an aspect of the event or discussion to previous experience/ideas.	*I knew that the plastic that the balloon [on the top of the cylinder] was made of wouldn't let the air through.*
Arriving at a developed and fuller idea to explain the event.	*I thought kind of at the time, oh, the air's light so that means it would've floated so the water must get in there somehow and then that's also when I started to get a bit clearer on how the water must be getting in.*
Confident that an idea is correct.	*Once I'd sort of figured out my answer was right . . .*

Cognitive Response	Example
Aware that an idea is incomplete with aspects unresolved.	John: *Er. I'm still working on my air pressure theory an what I said on the thing.* I: Uhuh. So it's not . . John: *Can't find any others [ideas] though.* I: It's not sort of complete yet. John: *No not totally.*

Table 3 Cognitive responses in Category 2: Information is sought from the materials

Cognitive Response	Example
Attempting to identify conditions relating to the event.	*I was trying to figure out . . . just what was in the glass and things.*
A thought experiment to test conditions.	*Ah, I was also wondering if . . . it'd work with anything apart from a balloon.*
Physically testing some aspects of the event to identify conditions or test an idea.	*[When I pushed on the balloon I] could feel the air pushing against [my] hand, and, like, if [I] pressed down with [my] finger, [I] could sort of like feel the water through the balloon and like the further [I] pushed down then the faster it went down.*

Table 4 Cognitive responses in Category 3: A verbal response in a social context

Cognitive Response	Example
Thinking of a question to ask.	*I [was] running anything through my head trying to think of a question to ask.*
Attempting to phrase a question for a yes/no answer.	*I sort of found it hard to ask the question. I couldn't word it right.*
Explaining to others an idea, prediction or observation.	I: What were you trying to say [to the group]? Colin: *Well I was trying to say the more you push it down the more it would go down.*

Table 5 Cognitive responses in Category 4: Information received from a social context

Cognitive Response	Example
Listening and trying to understand another.	*I was jus thinking about what [the other students] were saying.*
Comparing or contrasting others' ideas with one's own.	*Yeah it [another student's idea] fitted in with [my earlier idea about] the air pressure.*
Relating information provided to one's own ideas to reach understanding.	*I thought kind of at the time [when she explained her idea], oh, the air's light so that means it would've floated so the water must get in there somehow and then that's also when I started to get a bit clearer on how the water must be getting in [the small bottle].*
Another's idea triggers a new line of thought.	*He jus' said "air pressure" and I started thinking about air pressure.*
Taking a statement or action by the teacher as a hint to the right answer.	I: Did that example [provided by the teacher about putting a hole in the balloon] help? John: *Yeah. That's what gave me the hint that it worked on air pressure and things.*
Others' ideas being shared interferes with thinking an idea through.	*Yes, um, well when I started to get my own opinion on how the bottle rose and that or went back down, when other people had their ideas sometimes they were a bit different or completely different to my idea so then my thinking changed. I thought about their ideas and I started to get confused and then I lost what I thought about it and then I had to think it all back up again.*

Differences in Cognitive Responses Between Teaching Strategies

Differences and similarities in responses were also identified for the three teaching strategies employed in the study.

Category 1, a remembered idea is used. Responses such as recognising that no ideas came to mind, trying to think of an explanation, and arriving at a tentative explanation were used universally by the students regardless of the teaching strategy, as a consequence of some cognitive conflict being generated. Although most students felt confident in their explanations for the

discrepant event, few had a good grasp of the scientific answer. Perhaps having to struggle with more complex ideas which the student has to fit into some coherent explanation gives the subjective impression that the answer obtained is correct. Most of the students stated that they recognised their answer was incomplete.

Evaluation of ideas using new information was used in a limited way. Only five students used this response. Four of these were in the Suchman strategy, suggesting that this strategy may encourage this response. Denise, in the Liem strategy, also used the response.

Category 2, obtaining information from the materials. All students engaged in identifying conditions which were influencing the outcome of the discrepant event, but only the students in the Friedl strategy explored the materials directly, an obvious consequence of the hands on nature of the strategy, compared to the teacher demonstrations used in the other strategies. Opportunity for hands on exploration was considered important in working out ideas by many of the students, but not all.

Using thought experiments occurred most frequently in the Suchman strategy (five students), with two students each using it in the Liem and Friedl strategies.

Category 3, providing information. All students explained to others their observations, ideas and/or predictions, in all lessons. This occurred in both small groups and the whole class in the Suchman and Friedl lessons, because opportunity was given for both to occur in these. It occurred only in the whole class context in the Liem strategy because no small group discussion was permitted. Limited exchanges therefore took place.

The Suchman strategy was structured so that students would ask yes/no questions of the teacher. Therefore this type of response occurred only in the Suchman strategy. All students engaged in this, some to a lesser extent. Although these were verbal responses, their purpose was to obtain information, as a substitute for first hand exploration of the materials. Most students' questions tended to focus on conditions, rather than on devising thought experiments to test theories and then asking questions to obtain results for their thought experiment.

Category 4, receiving information. All students listened to the ideas of others, and most times compared what they heard to their own ideas. Leonie (Friedl) was less likely to do this than the other students. Five students used a previous lesson topic as a cue to finding an answer. As none of these were in the Friedl strategy, this suggests that this cue is used more frequently in teacher controlled lessons. Three students identified using statements or actions by the teacher as hints about the "correct" (i.e. the teacher's) answer. This cuing response therefore appears to be related to particular individuals instead of a strategy, though other students may have used it but not

been able to articulate their use of it, and so it remained undetected. For the students who used this response, it was a means of quickly ascertaining which ideas to pursue and which to ignore. Denise (Liem strategy) was able to explain her way of using cues, which revealed that most teacher actions of lesson structuring might potentially be used by students to obtain cues to the correct answer:

> I: Yeh. You were nodding there [in the video]. Did that mean you had an idea or what?
>
> Denise: I was just thinking, "No." That's why I shook my head just then because I knew [the answer another student had given to a teacher question] had nothing to do with that really, otherwise [the teacher] would have said, "See what I am doing," and he would have really emphasised it a bit more [when he did the demonstration].

This is a key component of the social context of lessons, and will operate regardless of the teaching strategy unless the teacher abrogates any lesson structuring responsibility. Even in the Suchman strategy, therefore, the teacher would be providing a series of cues for students able to discern them. However, the other strategies would contain more recognisable cues because they more closely resemble normal classroom teaching strategies.

Two other responses were used infrequently. Both appeared to be related to individual characteristics rather than teaching strategies. These were using another's idea to trigger a new line of thought, and the ideas of others causing confusion because they were not understood or they interfered with ideas being thought through. Both could occur as a result of comments made by the teacher or a peer, in small groups or the whole class. For instance, Leonie, Colin (both Friedl), and Thomas (Liem) experienced some confusion. For Thomas and Colin the confusion arose from the ideas of peers, whereas Leonie was confused by the teacher introducing scientific terms, which she did not understand.

Students' Progress Toward a Scientific Explanation

It is pertinent to note those students who achieved a reasonable grasp of the scientific principles involved in the discrepant event, even though only the first lesson in each strategy was observed. In the Suchman strategy, two students reached partial understanding. In the Liem strategy, four reached partial understanding, and two a good understanding, and in the Friedl strategy, two reached a partial understanding. The students most successful in arriving at something approaching the scientific explanation were those who had access to the explanations of others, and who had these ideas confirmed in some way. This therefore occurred more in the Liem and Friedl strategies, but only a limited number of students made reasonable progress. On the other

hand, motivation was highest in the Suchman strategy because the students knew they would not be provided with the answer.

The issue of the teacher providing the answer. Some students commented on the issue of the teacher not providing information, as in the Suchman strategy. They preferred not to be told the answers outright by the teacher, but liked to be able to think things through for themselves. However, they did want the teacher to provide guidance and help when they got into difficulties. They conceded that they tended to work harder towards finding an answer themselves if they knew the teacher was not going to tell them the answer -- but they still expected clarification of their answers at some later stage.

I:	Mm. Do you think it would be better for the teacher to tell you [the answer] straight off though?
Denise:	No, not really, because that way you don't really learn much as if you try to think through for yourself or discuss it with other people -- you're thinking about it and kind of involved with it and understanding it better -- it's better that way, um, like not having the teacher tell you straight off.

The teacher using the Suchman strategy also experienced unease in not providing confirmation of an answer.

Other results. Two other findings are worth noting. Firstly, in the Friedl strategy, the students were organised into groups of four. In both lessons, one student from each group who appeared to be less assertive than the others (a boy and a girl), also tended to be less engaged with the materials. The others in the group seemed to dominate the materials while the less assertive student observed. This raises queries whether groups of four are appropriate sized groups, and whether a maximum size of three would serve all students better. Secondly, most students tended to accept an approximate answer as sufficient, without exploring whether it was an adequate answer, or the extent to which it applied to the discrepant event situation. Intervention by the teacher or other students was the main determinant of whether they examined the tentative explanation more closely.

Discussion

The cognitive responses evidenced by the students included those predicted by theory, described earlier. However, they also included a number of responses not predicted. These, in particular, were related to the social context of the lessons, which was not prominent in the theories associated with discussions of discrepant events. This again highlights the need to include considerations of both internal processes to the learner, and social influences, as has been

advocated by several authors recently (e.g. Fensham, Gunstone, & White, 1994; O'Loughlin, 1992).

The Teaching Strategy and the Social Context

The data suggest that the teaching strategy used by the teacher can alter the social context of the lesson. Within the "school" setting and its general established social pattern, there can be many variations. Each strategy and lesson context appeared to establish its own variation of social rules for the classroom (Coles, 1992). The Liem strategy conformed most closely to what may be considered "traditional" or normal classroom social settings. The Suchman strategy differed in that the students were given the right to ask questions, and discuss ideas with each other, both within a limited and limiting framework. The Friedl strategy allowed students to interact with each other more freely, particularly in small groups as they worked with the equipment.

Discourse patterns. As a result of the different social settings and rules, different discourse patterns occurred. In the Liem strategy, the discourse followed the normal classroom pattern (Barnes & Todd, 1977; Cazden, 1988) of Teacher initiation - Student response - Teacher evaluation. In the Suchman strategy, the pattern was Student initiation - Teacher response - Student evaluation. The pattern was mainly Student - student turn taking in the Friedl strategy, with some brief episodes of Teacher initiation - Student response - Teacher evaluation.

Therefore, the types of thinking which occurred differed because the social setting and discourse patterns constrained student responses and thinking patterns available to the students. Because the Liem strategy resembled normal classroom settings, the responses of students and thinking characteristics used were those normally employed by the students in school. For example, students tended to wait for the answer to be provided, and compliantly finished a lesson with confusion remaining in the minds of four of the six students even though they were all supposed to have reached a good understanding of the discrepant event. As a further example, the Suchman strategy required students to generate their own questions and solutions, so their responses and thinking characteristics were directed towards this. Uncertainty about the different social setting generated by the Suchman strategy tended to limit the questions asked. As well, their only information sources were themselves, their small group, and the materials mediated indirectly through the teacher (by asking her questions). Consequently, their ability to arrive at an adequate explanation was limited. With the Friedl strategy, thinking was directed toward the materials, and to a limited extent, sharing understanding in the small group and later the whole group. For example, their thoughts tended to be more like "What will happen now? Why did that happen?" Although the materials provided much useful information in this strategy, the lack of any external input of ideas also proved a limitation on the extent to which the students could progress toward the scientific explanation.

The influence of the teaching strategy and social context. This suggests that the teaching strategy may determine students' information seeking behaviours and the sources of information available to the them. By determining the type of classroom interactions, the teaching strategy controls students' access to the available information. Each teaching strategy generates its own social context (Coles, 1992), part of which is control of the availability of information to students (Simons, 1979; Widdowson, 1987). Each strategy therefore makes information available in different ways (Appleton, 1995a). For instance, scaffolding by the teacher, as was evident in the Liem strategy, can help students achieve cognitive restructuring (Bruner, 1985; Driver, 1989). However, just because scaffolding is available to the student does not mean it is used effectively. Even with the best of intentions, some students seem to have processing and/or communication difficulties: they and the teacher fail in their attempts to reach mutual understanding. When a teacher is working with a whole class, a limited number of transactions can occur between the teacher and students, so the teacher is likely to attend to, and therefore scaffold with, a few students in the group. This may be because the teacher assumes that all students are following since none have indicated otherwise. (Most students in this study tended not to nominate ideas for fear of being publicly wrong, unless they were very confident in what they had to say.) It could also be because the teacher may feel inclined to progress with the lesson regardless of some students' lack of understanding because of perceived time constraints, or for fear of management problems if too much time is spent reviewing work already "covered."

Therefore, in the Liem strategy, information flow is controlled by the teacher (Barnes & Todd, 1977; Cazden, 1988; Edwards & Westgate, 1987), and could be couched in formal terminology if the teacher does not maintain mutual understanding with the students. On the other hand, information in a small group context is immediate, informal and could be used for mutual scaffolding of ideas (Bruner, 1985) such as occurred, for example, in the Suchman and Friedl lessons. Of all the strategies, the Liem strategy provided the most explicit scaffolded support for students (this would have occurred in the second lesson in the Friedl strategy, not observed in this study), which gave them the necessary help to achieve some understanding of the scientific principles of the discrepant event (Driver, 1989). However, this did not result in effective cognitive change for most students. The poor cognitive gains did not appear to be due to poor explanatory techniques, but may have been a consequence of scaffolding difficulties arising from the class size or from when the information was made available (Meyer & Woodruff, 1994).

Scaffolding by lesson structure. There were several instances recounted where students took cues from other lessons or from the teacher's structuring of the lesson. These, at least for some students, were another valuable source of information available from the social context. The teacher's planning should therefore embrace groups of lessons rather than isolated ones, and include details of what will be mentioned and highlighted, and what will not be mentioned. Both the presence and absence of specific statements by the teacher may be used by students to help

them reach conclusions. Students from other cultural groups could be expected to experience difficulties exploiting this source of information.

Another aspect of this was the importance of the teacher's intervention in encouraging students to move beyond an approximate answer toward a more detailed and coherent explanation. This can be achieved by both lesson structure and verbal comments or questions.

Authority of information sources. Information provided by peers has relative importance ascribed to it (Osborne & Wittrock, 1983), depending on the perceived ability of the student providing the information. For example, in the Friedl strategy, Colin saw a student in his group, Rhonda, as clever and so attended to her ideas rather than to those of Leonie. Information from the teacher has considerable status, as suggested by Denise's interpretation of the teacher's actions and non-actions as cues to the answer. However, information from the teacher can sometimes include unfamiliar terminology and cause confusion. The perceived importance or authority of the person providing the information determines how much notice of that information others take -- even if it is confusing.

Conclusion

This study has again emphasised the significance of the social context of science lessons in influencing the cognitive responses of students and their success in achieving understanding. Although the responses predicted from discrepant event-based cognitive theories were identified in this study, both these and unpredicted responses were influenced considerably by the social context, which was largely determined by the lesson strategy. As suggested by Ivany (1969), the extent to which information was available to students affected their level of understanding achieved by the end of the lesson, but the information also had to be available both at an appropriate time (a tentative conclusion not fully derived from the data, but identified by Meyer & Woodruff, 1994), in an appropriate form which the students could follow, and provided at a suitable pace for each student (Driver, 1989).

The cognitive responses emergent from this study provide insights into the thinking processes engaged in by students as they are confronted by discrepant events. The responses can be interpreted using a combination of cognitive and social constructivism, highlighting the necessity to consider the contribution of both to our understanding of learning in science (Cobb, 1994).

Since the selected teaching strategies were initially identified as differing in the extent to which they conformed to constructivist principles of learning, their indifferent success in achieving cognitive change is not surprising. If a more effective means of using discrepant events than these is to be found, ideas from social constructivism also need to be considered. The following

principles for teaching using discrepant events, based on constructivist principles of learning and highlighted by or emergent from this study, therefore emerge:

- The teacher should avoid confirming or denying the students' tentative solutions to the discrepant event, but provide clear guidance as to whether particular pathways or ideas are worth investigation. Confirmation may be appropriate at the conclusion of the unit of work, or after several lessons.

- The teacher needs to structure carefully both the lesson within the unit of work, and the sequence of events in the lesson to provide structuring cues for students. For students not well practised in identifying structuring cues, it may be necessary to point these out explicitly in a training sequence. This would be a particular imperative for students from other cultures (Appleton, 1995b).

- The students should be given the opportunity to interact with the discrepant event materials themselves, in small groups, preferably groups of three. This could occur after the event is demonstrated to the whole class.

- The students should engage in both small group and whole class discussions with the aim of finding a tentative solution. Groups may need to be structured in their operation if the students are unused to small group discussion (as was one class in this study). The whole class discussions should involve a form of reporting and evaluating the ideas and data emerging from the small groups.

- The teacher should ensure that several information sources are available to the students, and give some thought to how that information may be made understandable to the students so that it can be directly applied to the discrepant event situation.

These ideas are consistent with many of the teaching strategies based on constructivist thought which are currently being reported.

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